AUTOMATIC MESH SMOOTHING FOR FINITE ELEMENT MODELING FROM 3D IMAGE DATA

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Purpose

Automatic volumetric meshing algorithms on computerized tomography (CT) data have shown to be of great value for Finite Element (FE) modeling since they provide a fast and non-invasive way to study structural behavior. The interest on these methods has grown more since the apparition of microfocus CT (μCT) due to its high resolution, allowing assessment of mechanical behavior at a high precision. The basic meshing approach of generating hexahedra per voxel has the problem of producing jagged edges. Smoothing of the mesh can be then performed by using the Laplacian operator, but this method produces mesh shrinkage, which is unwanted in FE studies. In this paper an automatic meshing and smoothing algorithm for FE meshes from 3D image data is presented.

Methods

The method is based on low-pass signal filtering using transfer functions approximated by Chebyshev polynomials, resulting in a fast and computationally efficient method being extended here for FE meshes. The method includes a regularization step to assure good element's shape based on a quality measure. Although theoretically applicable for any type of mesh element, results are presented here for hexahedra meshes. The algorithm was evaluated using a thin walled sphere (radius: 30mm, thickness: 3mm) where an internal pressure of 10MPa was applied. The material was considered as isotropic and linear elastic (E: 12GPa and ν: 0.3). For such a problem the circumferential stress is given by the following equation:

$$\sigma = \frac{r \cdot p}{t} = \frac{30 \cdot 10}{3} = 100\ MPa \qquad (1)$$

This value represents the ideal solution, the discrete approximation of the geometry leads to a variation of this value. Simulations were done with ABAQUS (ABAQUS. Inc., Providence, RI, USA) for the unsmoothed voxel based mesh and for different levels of smoothing.

Results and discussion

The Mises stress was extracted for every integration point and plotted in a histogram showing the distribution of stress around the ideal solution of 100 MPa (figure, 1). In addition, the stability of the algorithm was studied in terms of number of warnings (given by ABAQUS due to distorted element shape) for different levels of smoothing (table, 1).

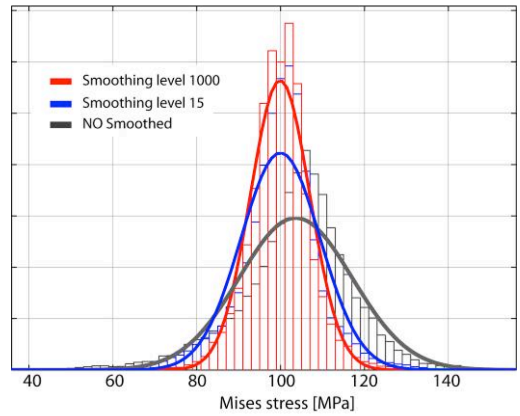

Figure 1: Distribution of stress on the elements of the sphere.

Smoothing level	Mean stress [MPa]	S.D.	Warnings
1000	99.9	7.1	23.4 %
100	100.46	7.9	19.4 %
15	99.97	9.4	12.1 %
NO smoothed	103.6	13.5	0 %

Table 1: Table captions are entered below the tables. Table text should use the standard font.

From figure 1 it can be seen an improvement after the smoothing on the mean value and standard deviation. As the level of smoothing increases the quality of the mesh decreases, which can be seen in column four of table 1. Nevertheless, this increase did not hinder the execution of the simulations (i.e. no errors). These results let us conclude that the proposed algorithm is capable of improving the results of voxel based finite element simulations.

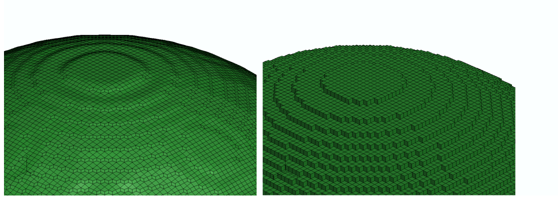

Figure 2: Detail of the smoothed (left) and non smoothed (right) mesh.

References

Boyd *et al*, J Biomech, 39:1287-1295, 2006.